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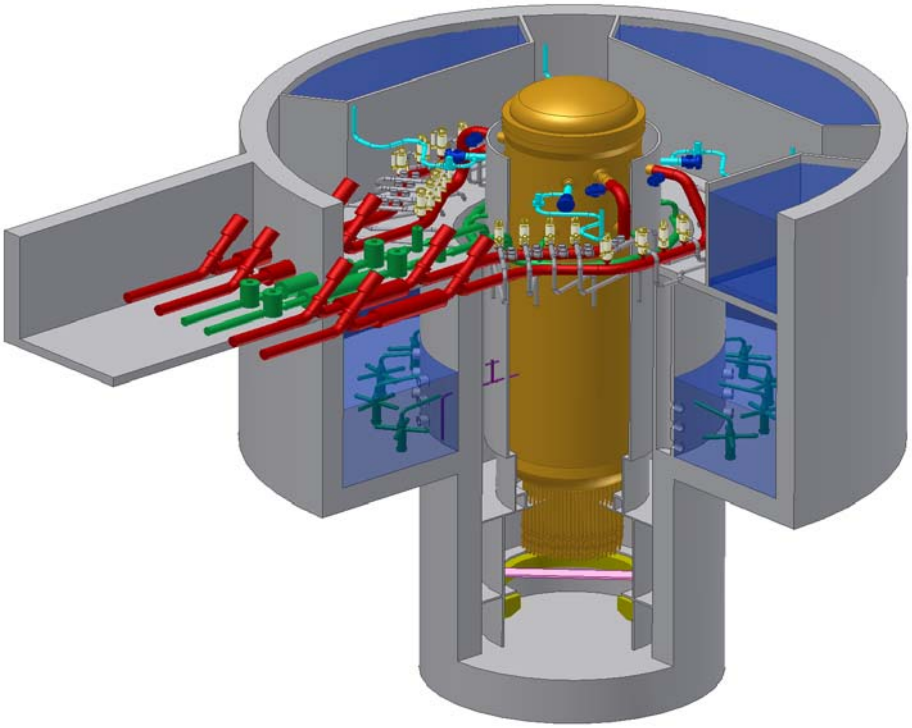

ESBWR Design Control Document

Tier 2

Chapter 9

Auxiliary Systems

Appendix 9B

Contents

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Global Abbreviations And Acronyms List

Term	Definition
10 CFR	Title 10, Code of Federal Regulations
A/D	Analog-to-Digital
AASHTO	American Association of Highway and Transportation Officials
AB	Auxiliary Boiler
ABS	Auxiliary Boiler System
ABWR	Advanced Boiling Water Reactor
ac / AC	Alternating Current
AC	Air Conditioning
ACF	Automatic Control Function
ACI	American Concrete Institute
ACS	Atmospheric Control System
AD	Administration Building
ADS	Automatic Depressurization System
AEC	Atomic Energy Commission
AFIP	Automated Fixed In-Core Probe
AGMA	American Gear Manufacturer's Association
AHS	Auxiliary Heat Sink
AHU	Air handling unit
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AL	Analytical Limit
ALARA	As Low As Reasonably Achievable
ALWR	Advanced Light Water Reactor
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
AOV	Air Operated Valve
API	American Petroleum Institute
APRM	Average Power Range Monitor
APR	Automatic Power Regulator
APRS	Automatic Power Regulator System
ARI	Alternate Rod Insertion
ARMS	Area Radiation Monitoring System
ASA	American Standards Association
ASD	Adjustable Speed Drive
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers

Global Abbreviations And Acronyms List

Term	**Definition**
AST	Alternate Source Term
ASTM	American Society of Testing Methods
AT	Unit Auxiliary Transformer
ATLM	Automated Thermal Limit Monitor
ATWS	Anticipated Transients Without Scram
AV	Allowable Value
AWS	American Welding Society
AWWA	American Water Works Association
B&PV	Boiler and Pressure Vessel
BAF	Bottom of Active Fuel
BHP	Brake Horse Power
BOP	Balance of Plant
BPU	Bypass Unit
BPWS	Banked Position Withdrawal Sequence
BRE	Battery Room Exhaust
BRL	Background Radiation Level
BTP	NRC Branch Technical Position
BTU	British Thermal Unit
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CAV	Cumulative absolute velocity
C&FS	Condensate and Feedwater System
C&I	Control and Instrumentation
C/C	Cooling and Cleanup
CB	Control Building
CBGAHVS	Control Building General Area
CBHVAC	Control Building HVAC
CBHVS	Control Building Heating, Ventilation and Air Conditioning System
CCI	Core-Concrete Interaction
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CIRC	Circulating Water System
CIS	Containment Inerting System
CIV	Combined Intermediate Valve
CLAVS	Clean Area Ventilation Subsystem of Reactor Building HVAC
CM	Cold Machine Shop
CMS	Containment Monitoring System
CMU	Control Room Multiplexing Unit

Global Abbreviations And Acronyms List

Term	Definition
COL	Combined Operating License
COLR	Core Operating Limits Report
CONAVS	Controlled Area Ventilation Subsystem of Reactor Building HVAC
CPR	Critical Power Ratio
CPS	Condensate Purification System
CPU	Central Processing Unit
CR	Control Rod
CRD	Control Rod Drive
CRDA	Control Rod Drop Accident
CRDH	Control Rod Drive Housing
CRDHS	Control Rod Drive Hydraulic System
CRGT	Control Rod Guide Tube
CRHA	Control Room Habitability Area
CRHAHVS	Control Room Habitability Area HVAC Sub-system
CRT	Cathode Ray Tube
CS&TS	Condensate Storage and Transfer System
CSDM	Cold Shutdown Margin
CS / CST	Condensate Storage Tank
CT	Main Cooling Tower
CTVCF	Constant Voltage Constant Frequency
CUF	Cumulative usage factor
CWS	Chilled Water System
D-RAP	Design Reliability Assurance Program
DAC	Design Acceptance Criteria
DAW	Dry Active Waste
DBA	Design Basis Accident
dc / DC	Direct Current
DCS	Drywell Cooling System
DCIS	Distributed Control and Information System
DEPSS	Drywell Equipment and Pipe Support Structure
DF	Decontamination Factor
D/F	Diaphragm Floor
DG	Diesel-Generator
DHR	Decay Heat Removal
DM&C	Digital Measurement and Control
DOF	Degree of freedom
DOI	Dedicated Operators Interface
DOT	Department of Transportation

Global Abbreviations And Acronyms List

Term	Definition
dPT	Differential Pressure Transmitter
DPS	Diverse Protection System
DPV	Depressurization Valve
DR&T	Design Review and Testing
DS	Independent Spent Fuel Storage Installation
DTM	Digital Trip Module
DW	Drywell
EB	Electrical Building
EBAS	Emergency Breathing Air System
EBHV	Electrical Building HVAC
ECCS	Emergency Core Cooling System
E-DCIS	Essential DCIS (Distributed Control and Information System)
EDO	Environmental Qualification Document
EFDS	Equipment and Floor Drainage System
EFPY	Effective full power years
EFU	Emergency Filter Unit
EHC	Electrohydraulic Control (Pressure Regulator)
ENS	Emergency Notification System
EOC	Emergency Operations Center
EOC	End of Cycle
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedures
EPDS	Electric Power Distribution System
EPG	Emergency Procedure Guidelines
EPRI	Electric Power Research Institute
EQ	Environmental Qualification
ERICP	Emergency Rod Insertion Control Panel
ERIP	Emergency Rod Insertion Panel
ESF	Engineered Safety Feature
ETS	Emergency Trip System
FAC	Flow-Accelerated Corrosion
FAPCS	Fuel and Auxiliary Pools Cooling System
FATT	Fracture Appearance Transition Temperature
FB	Fuel Building
FBFPHV	Fuel Building Fuel Pool Area HVAC
FBGAHV	Fuel Building General Area HVAC
FBHV	Fuel Building HVAC
FCI	Fuel-Coolant Interaction

Global Abbreviations And Acronyms List

Term	Definition
FCM	File Control Module
FCS	Flammability Control System
FCU	Fan Cooling Unit
FDDI	Fiber Distributed Data Interface
FFT	Fast Fourier Transform
FFWTR	Final Feedwater Temperature Reduction
FHA	Fire Hazards Analysis
FIV	Flow-Induced Vibration
FMCRD	Fine Motion Control Rod Drive
FMEA	Failure Modes and Effects Analysis
FPS	Fire Protection System
FO	Diesel Fuel Oil Storage Tank
FOAKE	First-of-a-Kind Engineering
FPE	Fire Pump Enclosure
FTDC	Fault-Tolerant Digital Controller
FTS	Fuel Transfer System
FW	Feedwater
FWCS	Feedwater Control System
FWS	Fire Water Storage Tank
GCS	Generator Cooling System
GDC	General Design Criteria
GDCS	Gravity-Driven Cooling System
GE	General Electric Company
GE-NE	GE Nuclear Energy
GEN	Main Generator System
GETAB	General Electric Thermal Analysis Basis
GL	Generic Letter
GM	Geiger-Mueller Counter
GM-B	Beta-Sensitive GM Detector
GSIC	Gamma-Sensitive Ion Chamber
GSOS	Generator Sealing Oil System
GWSR	Ganged Withdrawal Sequence Restriction
HAZ	Heat-Affected Zone
HCU	Hydraulic Control Unit
HCW	High Conductivity Waste
HDVS	Heater Drain and Vent System
HEI	Heat Exchange Institute
HELB	High Energy Line Break

Global Abbreviations And Acronyms List

Term	Definition
HEP	Human error probability
HEPA	High Efficiency Particulate Air/Absolute
HFE	Human Factors Engineering
HFF	Hollow Fiber Filter
HGCS	Hydrogen Gas Cooling System
HIC	High Integrity Container
HID	High Intensity Discharge
HIS	Hydraulic Institute Standards
HM	Hot Machine Shop & Storage
HP	High Pressure
HPNSS	High Pressure Nitrogen Supply System
HPT	High-pressure turbine
HRA	Human Reliability Assessment
HSI	Human-System Interface
HSSS	Hardware/Software System Specification
HVAC	Heating, Ventilation and Air Conditioning
HVS	High Velocity Separator
HWC	Hydrogen Water Chemistry
HWCS	Hydrogen Water Chemistry System
HWS	Hot Water System
HX	Heat Exchanger
I&C	Instrumentation and Control
I/O	Input/Output
IAS	Instrument Air System
IASCC	Irradiation Assisted Stress Corrosion Cracking
IBC	International Building Code
IC	Ion Chamber
IC	Isolation Condenser
ICD	Interface Control Diagram
ICS	Isolation Condenser System
IE	Inspection and Enforcement
IEB	Inspection and Enforcement Bulletin
IED	Instrument and Electrical Diagram
IEEE	Institute of Electrical and Electronic Engineers
IFTS	Inclined Fuel Transfer System
IGSCC	Intergranular Stress Corrosion Cracking
IIS	Iron Injection System
ILRT	Integrated Leak Rate Test

Global Abbreviations And Acronyms List

Term	**Definition**
IOP	Integrated Operating Procedure
IMC	Induction Motor Controller
IMCC	Induction Motor Controller Cabinet
IRM	Intermediate Range Monitor
ISA	Instrument Society of America
ISI	In-Service Inspection
ISLT	In-Service Leak Test
ISM	Independent Support Motion
ISMA	Independent Support Motion Response Spectrum Analysis
ISO	International Standards Organization
ITA	Inspections, Tests or Analyses
ITAAC	Inspections, Tests, Analyses and Acceptance Criteria
ITA	Initial Test Program
LAPP	Loss of Alternate Preferred Power
LCO	Limiting Conditions for Operation
LCW	Low Conductivity Waste
LD	Logic Diagram
LDA	Lay down Area
LD&IS	Leak Detection and Isolation System
LERF	Large early release frequency
LFCV	Low Flow Control Valve
LHGR	Linear Heat Generation Rate
LLRT	Local Leak Rate Test
LMU	Local Multiplexer Unit
LO	Dirty/Clean Lube Oil Storage Tank
LOCA	Loss-of-Coolant-Accident
LOFW	Loss-of-feedwater
LOOP	Loss of Offsite Power
LOPP	Loss of Preferred Power
LP	Low Pressure
LPCI	Low Pressure Coolant Injection
LPCRD	Locking Piston Control Rod Drive
LPMS	Loose Parts Monitoring System
LPRM	Local Power Range Monitor
LPSP	Low Power Setpoint
LWMS	Liquid Waste Management System
MAAP	Modular Accident Analysis Program
MAPLHGR	Maximum Average Planar Linear Head Generation Rate

Global Abbreviations And Acronyms List

Term	Definition
MAPRAT	Maximum Average Planar Ratio
MBB	Motor Built-In Brake
MCC	Motor Control Center
MCES	Main Condenser Evacuation System
MCPR	Minimum Critical Power Ratio
MCR	Main Control Room
MCRP	Main Control Room Panel
MELB	Moderate Energy Line Break
MLHGR	Maximum Linear Heat Generation Rate
MMI	Man-Machine Interface
MMIS	Man-Machine Interface Systems
MOV	Motor-Operated Valve
MPC	Maximum Permissible Concentration
MPL	Master Parts List
MS	Main Steam
MSIV	Main Steam Isolation Valve
MSL	Main Steamline
MSLB	Main Steamline Break
MSLBA	Main Steamline Break Accident
MSR	Moisture Separator Reheater
MSV	Mean Square Voltage
MT	Main Transformer
MTTR	Mean Time To Repair
MWS	Makeup Water System
NBR	Nuclear Boiler Rated
NBS	Nuclear Boiler System
NCIG	Nuclear Construction Issues Group
NDE	Nondestructive Examination
NE-DCIS	Non-Essential Distributed Control and Information System
NDRC	National Defense Research Committee
NDT	Nil Ductility Temperature
NFPA	National Fire Protection Association
NIST	National Institute of Standard Technology
NICWS	Nuclear Island Chilled Water Subsystem
NMS	Neutron Monitoring System
NOV	Nitrogen Operated Valve
NPHS	Normal Power Heat Sink
NPSH	Net Positive Suction Head

Global Abbreviations And Acronyms List

Term	Definition
NRC	Nuclear Regulatory Commission
NRHX	Non-Regenerative Heat Exchanger
NS	Non-seismic
NSSS	Nuclear Steam Supply System
NT	Nitrogen Storage Tank
NTSP	Nominal Trip Setpoint
O&M	Operation and Maintenance
O-RAP	Operational Reliability Assurance Program
OBCV	Overboard Control Valve
OBE	Operating Basis Earthquake
OGS	Offgas System
OHLHS	Overhead Heavy Load Handling System
OIS	Oxygen Injection System
OLMCPR	Operating Limit Minimum Critical Power Ratio
OLU	Output Logic Unit
OOS	Out-of-service
ORNL	Oak Ridge National Laboratory
OSC	Operational Support Center
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnect
P&ID	Piping and Instrumentation Diagram
PA/PL	Page/Party-Line
PABX	Private Automatic Branch (Telephone) Exchange
PAM	Post Accident Monitoring
PAR	Passive Autocatalytic Recombiner
PAS	Plant Automation System
PASS	Post Accident Sampling Subsystem of Containment Monitoring System
PCC	Passive Containment Cooling
PCCS	Passive Containment Cooling System
PCT	Peak cladding temperature
PCV	Primary Containment Vessel
PFD	Process Flow Diagram
PGA	Peak Ground Acceleration
PGCS	Power Generation and Control Subsystem of Plant Automation System
PH	Pump House
PL	Parking Lot
PM	Preventive Maintenance
PMCS	Performance Monitoring and Control Subsystem of NE-DCIS

Global Abbreviations And Acronyms List

Term	Definition
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PQCL	Product Quality Check List
PRA	Probabilistic Risk Assessment
PRMS	Process Radiation Monitoring System
PRNM	Power Range Neutron Monitoring
PS	Plant Stack
PSD	Power Spectra Density
PSS	Process Sampling System
PSWS	Plant Service Water System
PT	Pressure Transmitter
PWR	Pressurized Water Reactor
QA	Quality Assurance
RACS	Rod Action Control Subsystem
RAM	Reliability, Availability and Maintainability
RAPI	Rod Action and Position Information
RAT	Reserve Auxiliary Transformer
RB	Reactor Building
RBC	Rod Brake Controller
RBCC	Rod Brake Controller Cabinet
RBCWS	Reactor Building Chilled Water Subsystem
RBHV	Reactor Building HVAC
RBS	Rod Block Setpoint
RBV	Reactor Building Vibration
RC&IS	Rod Control and Information System
RCC	Remote Communication Cabinet
RCCV	Reinforced Concrete Containment Vessel
RCCWS	Reactor Component Cooling Water System
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RDA	Rod Drop Accident
RDC	Resolver-to-Digital Converter
REPAVS	Refueling and Pool Area Ventilation Subsystem of Fuel Building HVAC
RFP	Reactor Feed Pump
RG	Regulatory Guide
RHR	Residual heat removal (function)
RHX	Regenerative Heat Exchanger
RMS	Root Mean Square

Global Abbreviations And Acronyms List

Term	Definition
RMS	Radiation Monitoring Subsystem
RMU	Remote Multiplexer Unit
RO	Reverse Osmosis
ROM	Read-only Memory
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRPS	Reference Rod Pull Sequence
RSM	Rod Server Module
RSPC	Rod Server Processing Channel
RSS	Remote Shutdown System
RSSM	Reed Switch Sensor Module
RSW	Reactor Shield Wall
RTIF	Reactor Trip and Isolation Function(s)
RT_{NDT}	Reference Temperature of Nil-Ductility Transition
RTP	Reactor Thermal Power
RW	Radwaste Building
RWBCR	Radwaste Building Control Room
RWBGA	Radwaste Building General Area
RWBHVAC	Radwaste Building HVAC
RWCU/SDC	Reactor Water Cleanup/Shutdown Cooling
RWE	Rod Withdrawal Error
RWM	Rod Worth Minimizer
SA	Severe Accident
SAR	Safety Analysis Report
SB	Service Building
S/C	Digital Gamma-Sensitive GM Detector
SC	Suppression Chamber
S/D	Scintillation Detector
S/DRSRO	Single/Dual Rod Sequence Restriction Override
S/N	Signal-to-Noise
S/P	Suppression Pool
SAS	Service Air System
SB&PC	Steam Bypass and Pressure Control System
SBO	Station Blackout
SBWR	Simplified Boiling Water Reactor
SCEW	System Component Evaluation Work
SCRRI	Selected Control Rod Run-in
SDC	Shutdown Cooling

Global Abbreviations And Acronyms List

Term	Definition
SDM	Shutdown Margin
SDS	System Design Specification
SEOA	Sealed Emergency Operating Area
SER	Safety Evaluation Report
SF	Service Water Building
SFP	Spent fuel pool
SIL	Service Information Letter
SIT	Structural Integrity Test
SIU	Signal Interface Unit
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control
SLCS	Standby Liquid Control System
SLMCPR	Safety Limit Minimum Critical Power Ratio
SMU	SSLC Multiplexing Unit
SOV	Solenoid Operated Valve
SP	Setpoint
SPC	Suppression Pool Cooling
SPDS	Safety Parameter Display System
SPTMS	Suppression Pool Temperature Monitoring Subsystem of Containment Monitoring System
SR	Surveillance Requirement
SRM	Source Range Monitor
SRNM	Startup Range Neutron Monitor
SRO	Senior Reactor Operator
SRP	Standard Review Plan
SRS	Software Requirements Specification
SRSRO	Single Rod Sequence Restriction Override
SRSS	Sum of the squares
SRV	Safety Relief Valve
SRVDL	Safety relief valve discharge line
SSAR	Standard Safety Analysis Report
SSC(s)	Structure, System and Component(s)
SSE	Safe Shutdown Earthquake
SSLC	Safety System Logic and Control
SSPC	Steel Structures Painting Council
ST	Spare Transformer
STP	Sewage Treatment Plant
STRAP	Scram Time Recording and Analysis Panel
STRP	Scram Time Recording Panel

Global Abbreviations And Acronyms List

Term	Definition
SV	Safety Valve
SWH	Static water head
SWMS	Solid Waste Management System
SY	Switch Yard
TAF	Top of Active Fuel
TASS	Turbine Auxiliary Steam System
TB	Turbine Building
TBCE	Turbine Building Compartment Exhaust
TEAS	Turbine Building Air Supply
TBE	Turbine Building Exhaust
TBLOE	Turbine Building Lube Oil Area Exhaust
TBS	Turbine Bypass System
TBHV	Turbine Building HVAC
TBV	Turbine Bypass Valve
TC	Training Center
TCCWS	Turbine Component Cooling Water System
TCS	Turbine Control System
TCV	Turbine Control Valve
TDH	Total Developed Head
TEMA	Tubular Exchanger Manufacturers' Association
TFSP	Turbine first stage pressure
TG	Turbine Generator
TGSS	Turbine Gland Seal System
THA	Time-history accelerograph
TLOS	Turbine Lubricating Oil System
TLU	Trip Logic Unit
TMI	Three Mile Island
TMSS	Turbine Main Steam System
TRM	Technical Requirements Manual
TS	Technical Specification(s)
TSC	Technical Support Center
TSI	Turbine Supervisory Instrument
TSV	Turbine Stop Valve
UBC	Uniform Building Code
UHS	Ultimate heat sink
UL	Underwriter's Laboratories Inc.
UPS	Uninterruptible Power Supply
USE	Upper Shelf Energy

Global Abbreviations And Acronyms List

Term	Definition
USM	Uniform Support Motion
USMA	Uniform support motion response spectrum analysis
USNRC	United States Nuclear Regulatory Commission
USS	United States Standard
UV	Ultraviolet
V&V	Verification and Validation
Vac / VAC	Volts Alternating Current
Vdc / VDC	Volts Direct Current
VDU	Video Display Unit
VW	Vent Wall
VWO	Valves Wide Open
WD	Wash Down Bays
WH	Warehouse
WS	Water Storage
WT	Water Treatment
WW	Wetwell
XMFR	Transformer
ZPA	Zero period acceleration

9B. SUMMARY OF ANALYSIS SUPPORTING FIRE PROTECTION DESIGN REQUIREMENTS

9B.1 INTRODUCTION

This appendix is included to discuss in detail some of the analysis associated with the design decisions and requirements stated in Subsection 9.5.1.

9B.2 FIRE CONTAINMENT SYSTEM

As stated in Subsection 9.5.1, the fire containment system is the structural system and appurtenances that work together to confine the direct effects of a fire to the fire area in which the fire originates. The fire containment system is required to contain a fire with a maximum severity as defined by the time-temperature curve contained in ASTM E-119 for a fire with duration of three hours to separate redundant divisions of safe shutdown cables and equipment.

9B.3 FIRE TYPES

The fire containment system is capable of coping with the following three general types and magnitudes of fires:

(1) Three-Hour Fire

A three-hour fire is a fully involved fire producing a time-temperature profile equal to the standard ASTM E-119 time-temperature test curve for a time period of three hours. For this condition, the temperature in the room at the end of three hours is 1052°C (1926°F). Complete burnout of the fire area is assumed for a fire of this magnitude. No survival or recovery of equipment in the fire area is assumed. This capability of the fire containment system meets the requirements of NUREG-0800 SRP 9.5.1 and Branch Technical Position SPLB (Reference 9B-1).

It is unlikely that a true three-hour fire would ever occur as the fire would be limited to a lesser magnitude by fire suppression systems, available fuel, or available combustion air.

(2) Limited Growth Fire

A limited growth fire is a fire that produces a thermal column sufficient to create a heated layer of gases in the upper elevation of the room involved in the fire. Room flashover for this type of fire is prevented as a result of insufficient fuel, heat venting, or fire suppression activities. Although some of the equipment in the fire area would probably be unaffected by the fire, it is assumed that the function of all equipment in the fire area is lost.

(3) Limited Growth, Smoky Fire

A severely limited growth, smoky fire is a fire such as smoldering rags or an electrically initiated cable fire. The heat release from the fire is small so that the smoke is cooled by entrainment of air and the thermal column is thereby limited in size. Because the smoke is cold, its travel is highly influenced by the HVAC airflow patterns in the room. The fire does not affect most equipment in the fire area, although no credit is taken for the equipment remaining functional. It is possible, but highly unlikely, that this type of fire could progress to a limited growth or fully involved three-hour fire.

9B.4 FIRE BARRIERS

For the ESBWR design, the direct effects of a fire are confined to a single fire area by provision of three-hour rated fire barriers separating each fire area from adjacent fire areas. Rated three-hour fire barriers are formed by the following:

(1) Concrete fire barrier floors, ceilings, and walls that are at least six inches thick (Reference 9B-2, Figure 7-8T) if made from carbonate and siliceous aggregates. Other aggregates and thickness are acceptable if the type of construction has been tested and bears a UL (or equal) label for a three-hour rating.

(2) Partitions or other constructions such as steel stud and gypsum board partition walls that have been tested in accordance to Standard ASTM E-119 to have a fire rating of at least three hours.

(3) Rated fire doors with the label of a certified laboratory that indicates that the door and frame have been tested to the requirements of ASTM E-119 for a standard time-temperature curve for three hours.

(4) Penetration seals for process pipes and cable trays that have been shown by testing to withstand a fire equal to the rating of the barrier per the standard ASTM E-119 time-temperature curve. Certain penetrations, such as the containment penetrations, may be shown by analysis rather than test to have a fire resistance equal to at least a three-hour rating.

(5) Special assemblies and constructions as listed in subsection 9A.3.5 and 9A.3.6 of the Fire Hazard Analysis.

(6) Fire dampers are installed in HVAC ducts that penetrate rated fire barriers as required by NFPA 90A. Both the Reactor Building Controlled Area Ventilation System (CONAVS) and the Reactor Building Clean Area Ventilation System (CLAVS) have redundant fans that supply air through common ducts and redundant fans that exhaust air through common ducts. See Section 9.5.1.2.9.

The completeness of the barriers for the fire confinement system is examined and documented on a fire area by fire area basis in the fire hazard analysis, Appendix 9A.

9B.5 ALLOWABLE COMBUSTIBLE LOADING

Subsection 9B.4 documents that the ESBWR plant design provides capability by fire barriers to cope with a standard three-hour fire where necessary. The purpose of this subsection is to discuss this in terms of the expected and allowable combustible loading in the plant.

9B.5.1 Permanent Loading

The problem associated with predicting the allowable combustible loading compatible with a given fire rating is well stated in the NFPA Fire Protection Handbook (Reference 9B-2, p. 7-111).

"Technically accurate methods for relating fire severity, fire load, and fire resistance requirements are complex but can be advantageously used in important specific applications. Such methods require consideration of parameters other than the fuel load, such as ventilation, type of enclosure walls, and ceiling. These methods are complex and currently too difficult for general use in design or selection of barrier fire resistance."

Allowable fire loading for the ESBWR is developed on the basis of information available from industry experience and testing that classifies the types of occupancies, their combustible loads, and the expected fire severity that might occur in the occupancies. This information is used to approximately relate the fire loading and expected severity for the various types of occupancies. Three examples of how this is performed for the ESBWR design are provided.

- **Example 1:**

  The first example is taken from Table 7-9B of the NFPA Fire Protection Handbook (Reference 9B-2) and reproduced here as Table 9B-1. From the table, a fire as a result of ignition of ordinary combustibles (wood, paper and similar materials) with a heat of combustion of 16.3 MJ/kg (7,000 Btu/lbm) to 18.6 MJ/kg (8,000 Btu/lbm) and a loading of 146.5 kg/m^2 (30 lbm/ft^2) of floor area in a fire resistive building is estimated to produce a fire of a severity equivalent to the standard time-temperature curve for three hours. This equates to an average fire loading of 2,725 MJ/m^2 (240,000 Btu/ft^2). This is an indication of the capacity limit for the three-hour fire containment system for the ESBWR.

  In making the comparisons in the table, it is recognized that for two fires with different temperature histories, the fires may be considered to have equivalent severity when the areas under their time-temperature curves are equal.

  Burning rate is an indication of fire severity and therefore of interest. For this example, a three-hour fire loading with an average burning rate is 2,725 MJ/m^2 divided by 180 minutes, or 15.14 MJ/min/m^2 (1,333 Btu/min/ft^2).

- **Example 2:**

  Another method by which the allowable combustible loading may be determined is by reference to the information summarized in Figure 7-9B of Reference 9B-2, which is for zero to two hours. Figure 9B-1 is developed from that figure and extrapolated for the period of time of zero to three hours. Figure 9B-1 plots the standard fire endurance and time-temperature curves used for occupancy classifications "A" through "E" per Table 7-9E of Reference 9B-2 and is reproduced as Table 9B-2. The fire endurance curves indicate how long a fire burns based upon amounts of combustibles involved in the fire. The time-temperature curves indicate the severity expected for the various occupancies. There is no direct relationship between the straight and curved lines, but, for example, from the straight line portion of the curves, 48.8 kg/m^2 of ordinary combustibles per floor area (10 lbm/ft^2) is capable of producing almost a 90 minute fire in a "C" occupancy. The 90-minute fire is expected to have a severity equal to that of the curved line "C". As additional examples, 48.8 kg/m^2 of combustibles per floor area (10 lbm/ft^2) produces less than 75 and 60-minute fires in "D" and "E" occupancies, respectively. The fire severity follows their respective "D" and "E" time-temperature curves.

  Time-temperature curve "E" also represents the standard ASTM E-119 time-temperature curve. It is the design capability curve for the ESBWR. Given enough fuel and time, the severity of a fire in any of the types of occupancies eventually equals the standard time temperature curve. While fast-developing fires may peak above the standard curve in the early stages of fire development, they will tend to come back to or below the standard curve with time. This early peaking has little immediate effect on the life of fire barriers as they tend to respond to the area under the time-temperature curve more than to instantaneous values of temperature.

Figure 7-9B of the NFPA Fire Protection Handbook covers a time frame of two hours. Figure 9B-1 has been extrapolated to three hours. Note that the extrapolated fire endurance curve for an "E" type occupancy indicates that a combustible loading of 153.7 kg/m^2 (31.5 lbm/ft^2) produces a three hour fire. This corresponds well with the 146.5 kg/m^2 (30 lbm/ft^2) determined in Example 1.

Another point of reference is that, as indicated in Table 9B-2, non-combustible power houses fall in the occupancy group defined as "Slight" and have an expected fire severity curve of "A". The "A" group has the least fire severity of the five groups. It represents a minimum challenge to the "E" capability of the ESBWR. This is another indication of the margin provided by the three-hour barriers in the ESBWR design. Such activities as paper working, printing, furniture manufacturing and finishing are within the fire containment capabilities of the ESBWR three-hour fire barriers.

The fire endurance curve, extrapolated to three hours, for an "A" type occupancy, which includes noncombustible powerhouses, is approximately 39.1 kg/m^2 (8 lbm/ft^2) for a three-hour fire. This suggests that to be consistent with normal power plant design, combustible loading in any given area of the ESBWR is limited to the equivalent of 39.1 kg/m^2 (8 lbm/ft^2) of ordinary combustibles having a heat of combustion of 18.6 MJ/kg (8,000 Btu/lbm) and in a configuration that does not exceed an average burning rate of 4.04 $MJ/min/m^2$ (356 $Btu/min/ft^2$). There is margin for higher loadings, but they are considered on a case-by-case basis and eliminated if possible or protected by automatic suppression systems. For the ESBWR design, areas with permanent loadings higher than this magnitude are protected by automatic suppression systems, except for cable tray runs as discussed below.

As shown in Figure 9B-1, choosing the defined design limit in the above fashion gives a design margin for the ESBWR fire barriers (represented by the "E" curve) of 300% above the typical power plant combustible loading (represented by the "A" curve). While this is a rather large design margin, the uncertainties are also rather large.

- **Example 3:**

The British have graded building occupancies according to hazard by three classifications as determined by the fire load per floor area. The classifications are occupancies of low, moderate, and high fire load. The occupancy is defined as low if it does not exceed an average of 1,136 MJ/m^2 (100,000 Btu/ft^2) of net floor area of any compartment, or an average of 2,271 MJ/m^2 (200,000 Btu/ft^2) in limited isolated areas. Storage of combustible material necessary to the occupancy may be allowed to a limited extent if separated from the remainder and enclosed by appropriate grade fire-resistive construction. Examples of occupancies of normal low fire load are offices, restaurants, hotels, hospitals, schools, museums, public libraries, and institutional and administrative buildings.

At 39.1 kg/m^2 (8 lbm/ft^2) of combustibles with a heat of combustion of 18.6 MJ/kg (8,000 Btu/lbm) from Example 1 above, the combustible loading is 727 MJ/m^2 (64,000 Btu/ft^2). This is low fire load occupancy per the British classification system.

The normal combustible loading limit of 700 MJ/m^2 (61,640 Btu/ft^2) average and the electrical room combustible loading limit of 1,400 MJ/m^2 (123,280 Btu/ft^2) for limited areas is chosen on the basis of the above three examples. Over a three hour fire duration, these result in average burning rate densities of 3.89 MJ/m^2/min (342 Btu/ft^2/min) for all but electrical rooms and 7.78 MJ/m^2/min (684 Btu/ft^2/min) for electrical rooms.

9B.5.2 Transient Combustibles

The above design limits are also reasonable and acceptable for transient combustible loadings. Although there are many possible types of transient loads, one of the transient combustibles most likely to occur would be bags of protective clothing that might accumulate at a temporary change area. The justification of the acceptability of the stated design limit for this situation follows.

From the results of fire tests run at Southwest Research Laboratory and reported in Reference 9B-4, a 21.2 liter (5.6 gallon) bag of protective clothing weighs approximately 6.35 kg (14 lbm) and burns at an average peak rate of 5.28 MJ/min (5,000 Btu/min) with a total heat release of 148 MJ per bag (140,000 Btu per bag). The minimum required floor area per bag in the change area would therefore be the total combustibles per bag divided by the normal combustible loading limit, or 148 MJ (140,000 Btu) per bag divided by 700 MJ/m^2 (61,640 Btu/ft^2) which results in 0.21 m^2 (2.27 ft^2) per bag. In actuality, if the bags were stacked this tightly together their burning rate would be greatly reduced as compared to the test because the available burning surface per bag would be greatly reduced. The calculation points out that a reasonable number of bags of protective clothing (up to four) located in a temporary change area would not materially threaten the limits of the fire tolerance of the plant.

Combustible liquid spills, such as lubricating oil or diesel oil, are another type of transient combustible that might be introduced into the plant during normal operation and maintenance. Although combustible liquids are required to be kept in approved containers, the possibility of a spill exists. Per Table 7-11A of the NFPA Fire Protection Handbook, (Reference 9B-2), the acceptable size for a spill may be estimated on the basis that these types of liquids burn in a pool with a heat release rate of approximately 200 Btu/sec/ft^2, which is equivalent to 136.3 MJ/min/m^2 (12,000 Btu/min/ft^2). This is equal to an energy release of 8,176 MJ/m^2 (720,000 Btu/ft^2) in one hour. The percent of room area which could be covered by a spill and still be within the defined design limit is 8.6% (700 MJ/m^2 divided by 8,176 MJ/m^2). In other words, a 10 m by 10 m (32.8 ft by 32.8 ft) room with negligible quantities of permanently installed combustibles could have an oil spill covering 8.6 m^2 (92.2 ft^2), burn for one hour, and still be within the combustible loading design limit.

It is not intended that the defined design limit be rigidly applied to spills, as they would occur very infrequently and be cleaned up quickly. The example is included here to give an indication of the size of a spill that would be consistent with the restrictions of the defined design limit. It validates the requirement to store combustible liquids in limited quantities in approved containers.

The example also points out the necessity to provide automatic fire suppression for areas where oil spills that could cover the entire floor area of a room are possible.

9B.5.3 Cable Trays

Insulation for electrical cables in cable trays is the major contributor to permanent combustible loading throughout the plant. For this reason cable trays are worthy of specific attention.

Cable trays, 0.61 m (24 in.) wide and in stacks two trays wide and three trays high (six 0.61 m wide trays or equivalent), are permitted without fixed automatic fire suppression in general plant areas. The acceptability of this configuration is analyzed in at least two ways. One method (Total Combustible Cable Insulation Per Area) calculates the total combustible loading per area of stack and limits the width of the room through which the tray stack passes or the distance between the two-by-three stack and any additional stacks in the room to maintain the combustible loading per floor area per length of tray to no more than the design limit value. The second method (Burning Rate of Cable Insulation) calculates the burning rate for the plastic insulation on the cables and restricts the quantities of cables length of cable tray stack to a value that will provide a heat release rate equal to or less than the burning rate density limit of 3.89 $MJ/m^2/min$ (342 $Btu/ft^2/min$). These two calculations and their results are provided below.

Total Combustible Cable Insulation Per Area

From previous plant design experience the average weight of insulation per cable tray area is 48.8 kg/m^2 (10 lbm/ft^2) for cross-linked polyethylene (XLPE-FR). With a heat of combustion of 29.8 MJ/kg (12,800 Btu/lbm), a six tray stack of 0.61 m (24 in.) wide cable trays represents a heat load of 5,320 MJ/m (1,540,000 Btu/ft). For the stack of six 0.61 m (24 in.) wide cable trays to be routed through the entire length of a room such as a corridor without exceeding the normal combustible loading limit is 700 MJ/m^2 (61,640 Btu/ft^2), the room is required to have a minimum width of 7.6 m (25 ft), determined by 5,320 MJ/m of cable tray stack divided by 700 MJ/m^2.

Since the above is based on averages a specific calculation is warranted. Cross-linked polyethylene, flame retardant (XLPE-FR) and Tefzel (Registered trademark, E.I. Du Pont De Nemours & Co. Inc.) are two types of cable insulations that are commercially available and for which standard constructions are compared in Table 9B-3.

In the above tabulation, either 94 or 37 cables represent a design maximum fill of 40% for the two sizes of XLPE-FR insulated cables, with a maximum combustible loading of 1,613 MJ/m^2 (142,000 Btu/ft^2). Either 202 or 58 cables represent 40% fill for Tefzel insulated cables, with a maximum combustible loading of 550 MJ/m^2 (48,400 Btu/ft^2). To stay within the allowable average combustible loading of 700 MJ/m^2 (61,640 Btu/ft^2), each meter of 0.61 m (24 in.) wide cable tray loaded to 40% fill with XLPE-FR insulated cables requires approximately 1.4 m^2 (15 ft^2) of floor area, determined by 0.61 m (2 ft) times 1 m (3.28 ft) times 1,613 MJ/m^2 (142,000 Btu/ft^2) divided by 700 MJ/m^2 (61,640 Btu/ft^2). Similarly, each meter of 0.61 m (24 in.) wide cable tray loaded to 40% fill with Tefzel insulated cables requires approximately 0.5 m^2 (5.2 ft^2) of floor area, determined by 0.61 m (2 ft) times 1 m (3.28 ft) times 550 MJ/m^2 (48,400 Btu/ft^2) divided by 700 MJ/m^2 (61,640 Btu/ft^2) to stay within the allowable average combustible loading limit. A 40% fill would provide almost twice as many Tefzel insulated cables as XLPE-FR insulated cables.

A reduced diameter cross-linked polyethylene cable (XLR) is available. Its combustible loading and quantity of cables per a given tray width approaches that of Tefzel insulated cables and either type would be quite viable for use in the ESBWR.

Burning Rate of Cable Insulation

Although, the effect on the fire barriers is dependent on the integral of the time-temperature curve more than the peak burning rate, the maximum burning rate that is possible with the allowable combustible load is still of interest.

Burning rate is dependent on the amount of surface area available to burn, the amount of oxygen available for the combustion process, and the properties of the combustible. For a solidly-filled ladder cable tray with one full layer of cables, the surface available for the instantaneous combustion process is the total of the circumferences of the individual cables times the length of the cables. This equates to being pi times the width of the tray times the length of the tray. For a tray 0.61 m (24 in.) wide and 1 m (3.28 ft) long, the cable surface area available for burning is 1.92 m^2 (20.6 ft^2). This is the maximum available burning surface as the top and bottom surface area is unchanged for additional layers of cables. The 0.102-meter (4 in.) deep side rails protect the sides of the cable stack in the trays, so that they do not receive combustion air.

A summary of burning rate calculations is presented in Table 9B-4 by source and material type.

The burning rate for cross-linked polyethylene was calculated by use of equation 2 from Section 5.3 of Attachment 10.4 of the draft of the Fire Vulnerability Evaluation (FIVE) (Reference 9B-4). For this calculation, the peak heat release rate is:

$$Q_{fs} = 0.45 \text{ qbs } A \qquad (9B\text{-}1)$$

where "qbs" is the bench scale-burning rate taken from Table A-7M of Attachment 10.7 of the Fire Vulnerability Evaluation document (Reference 9B-4) and "A" is the burning surface area.

The data estimated from tests at UL was taken from a series of modified IEEE 383 tests conducted in 1976 (Reference 9B-5). Although it was not the purpose of the tests to determine burning rate, it is possible to estimate the burning rate from the reported insulation consumed and cable burning time as determined by time-tagged photographs of the tests in progress. Cross-linked polyethylene and Tefzel insulated cables of the constructions discussed earlier in this section (Table 9B-3) were tested with the range of burning rates indicated in Table 9B-4 as the results.

The ventilation limited burning rate was calculated using the Fire Vulnerability Evaluation methodology using the Draft Fire Vulnerability Evaluation Plant Screening Guide (Reference 9B-4). The equation is:

$$Q_{max}/V = 3600 \text{ kW}/(m^3/\text{sec}) \qquad (9B\text{-}2)$$

where "Qmax" is the maximum heat release rate in kilowatts and "V" is the volume flow in cubic meters per second. Converting to English units:

$$Q_{max}/V = 96.6 \text{ (Btu/min)}/(ft^3/\text{min}) \qquad (9B\text{-}3)$$

For 1 m^2 (10.8 ft^2) of a room with a ceiling height of 4.57 m (15 ft) and a ventilation rate of 3 air changes per hour, the ventilation rate is 0.00381 m^3/sec (8.1 cfm). Q_{max} is equal to:

$$Q_{max} = 3600 \text{ kW/(m}^3\text{/sec) x } 0.00381 \text{ m}^3\text{/sec} = 13.7 \text{ kW} = 823 \text{ MJ/min (780 Btu/min)} \quad (9B\text{-}4)$$

over the 1 m^2 (10.8 ft^2) floor area.

The burning rate for the design normal combustible load limit is the combustible load limit of 700 MJ/m^2 (61,640 Btu/ft^2) as defined in Subsection 9B.5.1, divided by 180 minutes (3 hours), which results in 3.89 MJ/min/m^2 (342 Btu/min/ft^2).

Similarly, the equivalent burning rate of 15.14 MJ/min/m^2 (1,333 Btu/min/ft^2) for the fire barrier capability is the 2,725 MJ/m^2 capability of the three-hour barrier divided by 180 minutes.

The normal combustible load limit of 3.89 MJ/min/m^2 (342 Btu/min/ft^2) divided into the burning rate of 6.99 to 37.85 MJ/min/m^2 (615 to 3,333 Btu/min/ft^2) of open ladder cable tray gives an allowable minimum ratio of 1.8 to 9.7 of floor area to cable tray area within a room, depending on the type of cable insulation used.

The value of the burning rate calculations is that they give an idea of what the localized burning rate might be for a cable fire that is not burning in the ventilation controlled mode. Multiple trays of cables should not be run in rooms such as oil storage tank rooms where there would be an ignition source sufficiently large to ignite the entire amount of cable in the room. Also, areas containing potential ignition sources sufficiently large to ignite large amounts of cables have sprinkler type suppression systems. For these reasons, the normal combustible loading limit, based on the total combustible per square foot, should be used in preference to using the localized burning rate as the basis for setting the limit.

One additional comment is that the low ventilation controlled burning rate of 823 MJ/min of floor area as compared to the barrier system capacity of 15.14 MJ/min/m^2 (1,333 Btu/min/ft^2) as determined previously in Example 1 of Subsection 9B.5.1 is another indication of the design margin that is provided by the three-hour fire barrier system. The capacity of the barrier system is not approached by the fire intensity, except possibly during the time when the ventilation rate to the area experiencing the fire has been increased to facilitate fire suppression activities.

It is possible that during the detailed design phase certain areas of concentration of cable trays may exceed the normal or electrical combustible loading limit. Multiplexing of signals and the overall plant layout tends to minimize the number of these areas of concentration of cable trays. Options are available to the detail designer to allow specific concentrations of cable tray above the general stated combustible loading limits. For example, the designer could use one or more of the following options:

- **Option 1**

  One option is to use cable insulation with a lower required thickness, a low heat of combustion, or a low burning rate. The number of cable trays could be held constant or the same number of cables could be routed through fewer cable trays.

- **Option 2**

  A second option is to utilize cable trays with solid bottoms and solid covers for congested areas.

9B.6 REFERENCES

9B-1 U.S. Nuclear Regulatory Commission, “Standard Review Plan, NUREG-0800,” Revision 4.

9B-2 Cote, Arthur E., “NFPA Fire Protection Handbook,” National Fire Protection Association, Sixteenth Edition.

9B-3 General Electric Company, “TVA STRIDE Fire Hazard Analysis, C.F. Braun & Co.,” Project 4840-P, Rev. 1, May 1977.

9B-4 Electric Power Research Institute, Palo Alto, CA, “Professional Loss Control, Fire Vulnerability Evaluation Methodology (FIVE) Plant Screening Guide,” Draft, EPRI7.REV, Contract No. RP 3000-41, 1990.

9B-5 E.I. Du Pont De Nemours & Co. Inc., “Flame Tests, A report on tests conducted by Underwriters Laboratories, Inc., E-12952, at Northbrook, Illinois,” September 27, 28 and 29, 1976.

Table 9B-1

Estimated Fire Severity for Offices and Light Commercial Occupancies

Combustible Content* kg/m^2 (lbm/ft^2)	Assumed** Heat Potential MJ/m^2 (Btu/ft^2)***	Equivalent Fire Severity (hr)****
24.4 (5)	454 (40,000)	0.5
48.8 (10)	908 (80,000)	1.0
73.2 (15)	1362 (120,000)	1.5
97.6 (20)	1817 (160,000)	2.0
146.4 (30)	2724 (240,000)	3.0
195.2 (40)	3634 (320,000)	4.5
244.0 (50)	4315 (380,000)	7.0
292.8 (60)	4906 (432,000)	8.0
341.6 (70)	5678 (500,000)	9.0
Data applies to fire-resistive buildings with combustible furniture and shelving*****		

* Total, including finish, floor, and trim.

** Heat of combustion of contents taken at 8,000 Btu/lbm up to 40 lbm/ft^2; 7,600 Btu/lbm for 50 lbm/ft^2, and 7,200 Btu/lbm for 60 lbm/ft^2 and more to allow for relatively greater proportion of paper. The weights contemplated by the tables are those of ordinary combustible materials, such as wood, paper, or textiles.

*** SI units: 1 lbm/ft^2 = 4.88 kg/m^2; 1 Btu/ft^2 = 0.0114 MJ/m^2

**** Approximately equal to that of a test under the standard curve for the listed periods.

***** Reproduced from Table 7-9B, NFPA Fire Protection Handbook, Reference 9B-2.

Table 9B-2

Fire Severity Expected by Occupancy*

Temperature Curve A (Slight)
Well-arranged office, metal furniture, noncombustible building. Welding areas containing slight combustibles. Noncombustible power house. Noncombustible buildings, slight amount of combustible occupancy.
Temperature Curve B (Moderate)
Cotton and waste paper storage (baled) and well-arranged, noncombustible building. Papermaking processes, noncombustible building. Noncombustible institutional buildings with combustible occupancy.
Temperature Curve C (Moderately Severe)
Well-arranged combustible storage, e.g., Wooden patterns, noncombustible buildings. Machine shop having noncombustible floors.
Temperature Curve D (Severe)
Manufacturing areas, combustible products, noncombustible building. Congested combustible storage areas, noncombustible building.
Temperature Curve E (Standard Fire Exposure-Severe)
Flammable liquids. Woodworking areas. Office, combustible furniture and buildings. Paper working, printing, etc. Furniture manufacturing and finishing. Machine shop having combustible floors.

* Reproduction of Table 7-9E, (Reference 9B-2). See Figure 9B-1 for the temperature curves identified in this table.

Table 9B-3

Cable Type and Configuration for UL Tests*

Cable Type	Cables Per Tray 0.304 M (1 Ft) Wide	Tray Combustible Loading MJ/m^2 (Btu/ft^2)
7/C#14AWG XLPE-FR	94	1,613 (142,000)
7/C#14AWG Tefzel	94	256 (22,500)
7/C#14AWG Tefzel	202	550 (48,400)
19/C#14AWG XLPE-FR	37	1,544 (136,000)
19/C#14AWG Tefzel	37	200 (17,600)
19/C#14AWG Tefzel	58	313 (27,600)

* (This table is reproduced from Reference 9B-5)

Table 9B-4

Summary of Burning Rate Calculations

Material/Design Limit	Source of Data	Burning Rate*	Burning Rate**
Cross-linked Polyethylene	FIVE bench scale burning data (Ref. 9B-2)	10.417 (917.3)	32.724 (2882)
Cross-linked Polyethylene	Estimated from tests at UL (Ref. 9B-5)	6.67 to 12.05 (587.3 to 1061)	20.955 to 37.853 (1845 to 3333)
Tefzel	Estimated from tests at UL (Ref. 9B-5)	2.22 to 4.367 (195 to 385)	6.988 to 13.716 (615 to 1208)
Ventilation limited (Three air changes per hour)	FIVE Plant Screening Guide, Equation 47 of Attachment 10.7 (Ref. 9B-4)		0.820 (72.2)
Design normal maximum limit	Typical for power houses (Ref. 9B-2)		4.040 (356)
Fire barrier capability	ASTM E-119 curve for three hours		15.123 (1332)

* MJ/min per m^2 of surface area (Btu/min/ft^2)
** MJ/min per m^2 of cable tray or floor area (Btu/min/ft^2)

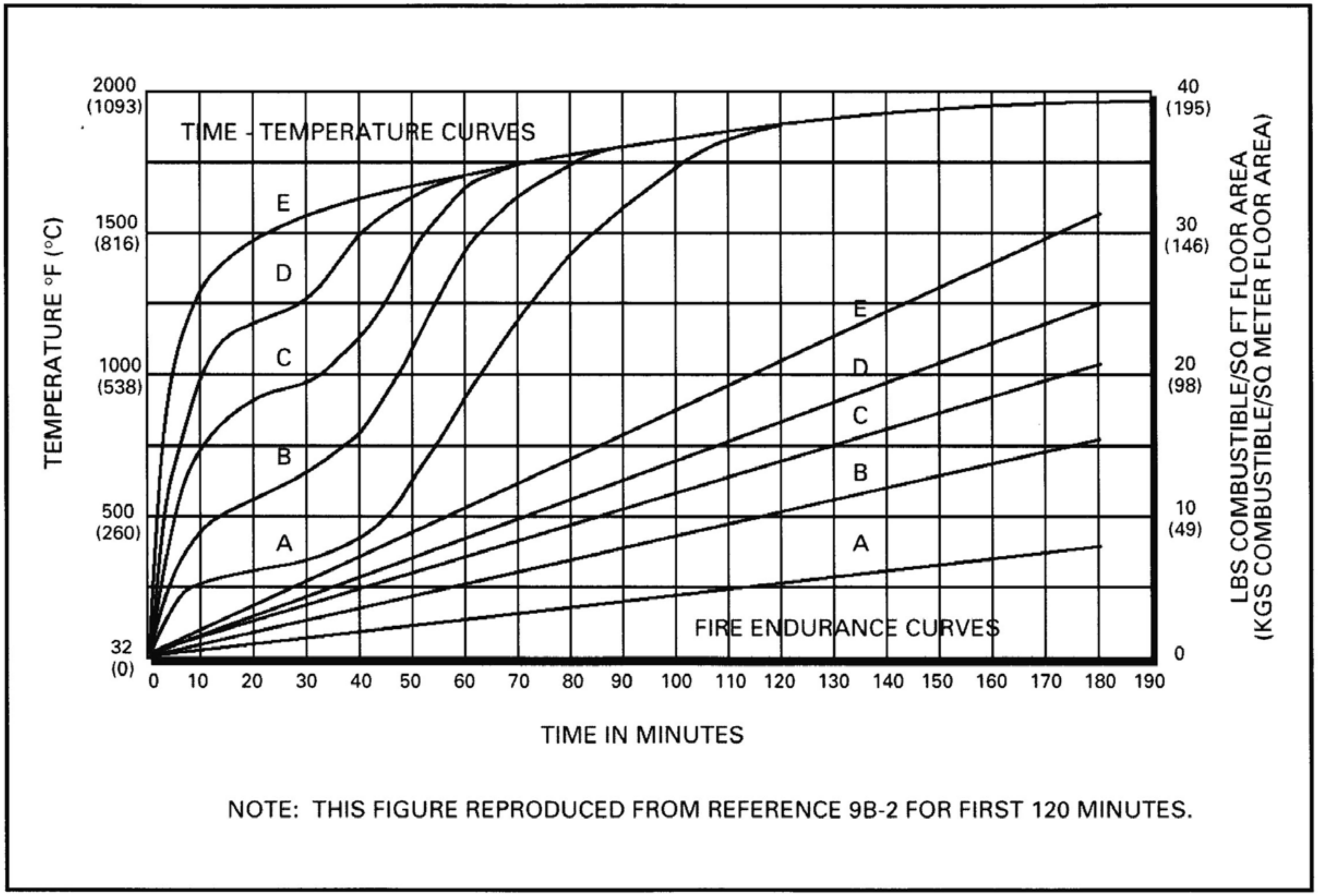

Figure 9B-1 Time-Temperature Curve and Fire Endurance Curves